European Commission DG Environment / European Chemicals Agency (ECHA)

The use of PFAS and fluorine-free alternatives in fire-fighting foams

Stakeholder workshop background paper

Tuesday 24 September 2019 at ECHA, Helsinki.

Wood Environment & Infrastructure Solutions UK Limited – September 2019

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Report for

Workshop participants

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1. Introduction

The European Chemicals Agency (ECHA) is hosting a workshop on Tuesday 24th September 2019 in Helsinki to discuss the use of Per-and polyfluoroalkyl substance (PFAS) -based fire-fighting foams as well as fluorine-free alternatives.

This workshop forms part of a wider study being undertaken jointly by the European Commission, DG Environment ('DG ENV') and by ECHA examining the use of PFAS and their alternatives in fire-fighting foams and identifying the most appropriate instrument for possible regulatory risk management activities.

The purpose of the workshop is to present, validate and seek feedback on the preliminary project findings, gather views on possible risk management options and explore the feasibility of replacing PFAS-based foams with fluorine-free alternatives. Stakeholder views will be sought during the workshop through a series of breakout groups on key topic areas which will focus on specific questions designed to inform possible future regulatory activities.

1.1 This report

This pre-workshop report is split into two sections and contains firstly, further information on the context and purpose of the workshop, the workshop format and some thought-starter questions for participants. The second half of this report includes preliminary results for the project and remaining work to be completed, including aspects where we are seeking further stakeholder input.

1.2 Workshop context

Wood has been contracted by DG ENV and ECHA to provide services on two concurrent contracts:

- "The use of PFASs and fluorine-free alternatives in fire-fighting foams" (the 'DG ENV study') ; and
- "Assessment of alternatives to PFAS-based fire-fighting foams and the socio-economic impacts of substitution" (the 'ECHA study').

Wood is working in partnership with Ramboll on the DG ENV study and with COWI on the ECHA study, acting as subcontractors to Wood in both cases.

As a whole, the project aims to provide an assessment on the use of PFAS and their alternatives in fire-fighting foams and to identify the most appropriate instrument for possible regulatory risk management activities. Addressing both concerns resulting from the continued use of PFAS in fire-fighting foams and assessing potential socio-economic impacts of any regulatory activities.

The Commission study will gather information as a basis for a decision on the appropriate regulatory measures to control the risks associated with PFAS. This study specifically covers the use of PFAS substances and fluorine-free alternatives in fire-fighting foams including information such as their volumes of use, their functionality, emissions to the environment and the costs of remediation of soil and water due to environmental release. Consideration will be given to foams already on the market and installed in systems, as well as those foams not yet in use.

At this stage of the project we have collated information from the literature and stakeholder questionnaires on the identification, functionality and volumes of substances used within PFAS-based and fluorine-free alternatives. **However, for the next stage of analysis we require further input from stakeholders on the remaining data gaps around revenues from sales of PFAS-containing foams and fluorine-free foams in the EU, trends and drivers in foam sales, differences in remediation practices between PFAS-based and fluorine free foams and the possible implications of different risk management options. These are therefore the key topics for further discussion at the workshop.**

The ECHA study will support the DG ENV study by performing part of the assessment on availability of alternatives and socio-economic impacts of a possible restriction. More specifically, the objectives of the ECHA contract are to assess the technical feasibility, economic feasibility, and availability of alternatives to PFAS-based fire-fighting foams, as well as the socio-economic impacts of substitution.

Currently under the ECHA project, we have identified a long list of fluorine-free alternatives that are available on the market and from the literature/stakeholder questionnaires we have some details on their associated technical feasibility and cost.

Information gaps remain regarding which specific alternatives are being used in the EU and the costs of replacing equipment associated with switching to alternative foams and/or potential savings associated with switching to fluorine-free alternatives. Each of these components will feed into the pre-regulatory management option analysis (RMOA) and (pre) Annex XV dossier report that will be developed in the Commission study and hence the need for a shared stakeholder workshop to seek further (your) input on the topics of availability and technical/economic feasibility of fluorine-free alternatives.

For both studies to be effective in considering possible future regulatory risk management activities, engagement with a wide range of stakeholders is paramount. A questionnaire has already been issued to a large number of stakeholders however we are hosting this workshop to engage further with additional stakeholders on this topic to gather your views and opinions on the use of PFAS-based firefighting foams and fluorine-free alternatives. The workshop will host 30-40 participants from all interested sectors and will be conducted over a single day at ECHA.

1.3 Purpose of the workshop

Over recent months, the Commission and ECHA have contacted industry, NGOs, airports, government authorities, military, users, manufacturers and technical experts in order to better understand the use of PFAS-based and fluorine-free (alternative) fire-fighting foams in the EU. The preliminary outcomes of this first stage of the consultation (via questionnaire) are presented in the second half of this report and will be discussed further during the workshop.

The aim of the workshop is to present, validate and seek feedback on the project findings so far and to gather views on possible risk management options; the functionality/feasibility of alternatives; preliminary estimates of environmental emissions of PFAS and alternatives; and remediation costs following foam use.

During the workshop, you the stakeholders will have the chance to provide your insights on the technical and economic feasibility of alternatives for a range of application scenarios (e.g. different fire types, sector-specific practices and infrastructure etc.), as well as the benefits associated with alternatives (e.g. lower clean-up costs after each application). The workshop will also be an opportunity to present hypothetical risk management scenarios and assess stakeholder concerns around associated socio-economic implications, e.g.

health, safety and environmental impacts, infrastructure upgrades, impacts on employment, and competitiveness of EU firms.

1.4 Format of the workshop

The workshop will begin with a plenary session on the regulatory background of the project and the preliminary findings on substance identity of foam products, market analysis and availability of fluorine-free alternatives. After this, participants will have an opportunity to comment and discuss each topic in an open forum. Following this discussion session, four individual spotlight presentations will take place with invited speakers from some of the major fire-fighting foam sectors including both manufacturers and users.

After lunch there will be a series of breakout groups in which the proposed RMOs, alternatives, remediation of PFAS and current/future trends in PFAS-based foam use will be discussed in more detail. There will be four breakout groups in the afternoon session and participants will be allocated their first group discussion and then have the opportunity to move between two further chosen topic areas of interest. Group facilitators and participants will then report back from the breakout groups in the late afternoon, and the workshop conclusions will be taken into account by Wood, ECHA and the Commission. For detailed timings please refer to the accompanying agenda.

1.5 Where we would like your help

The primary aim of the workshop is to seek stakeholder input on possible risk management options for fire-fighting foams; the functionality of fluorine-free alternatives; remediation costs following foam use; and future market trends of PFAS-based and fluorine-free foams. Each of these topics will be discussed during a series of breakout groups in the afternoon of the workshop where we would **like you to share your experiences/insights and any key case study examples**.

For each group, there will be a facilitator/ rapporteur who will lead and report back on the discussions during the final plenary session. The facilitators/ rapporteurs will be from the Wood project team. The format for the breakout groups will include a brief reminder of the key topic areas and project findings (presented in the morning plenary session), followed by feedback from the group on possible risk management options **(RMOs), alternatives, remediation costs and future (market) trends** in foam use.

For each of the topic areas, we have provided a series of thought-starter questions (Table 1.1). ***Please consider these questions in advance of the workshop and bring any necessary reports or materials with you, if required.***

Table 1.1 Topic area and starter questions for workshop breakout discussion groups

1. Different Risk Management Options (RMOs)

What are the potential impacts of:

- different transition periods for phasing out PFAS in firefighting foams?
- different threshold concentrations of PFAS (i.e. impurity levels) in firefighting foams once the potential future regulation is in place? (e.g. what are the cost to clean up the installation associated with specific PFAS impurity thresholds)
- restrictions on either new PFAS-containing firefighting foam products entering the market only vs restrictions on both new PFAS-containing foam products and those already in use in existing systems?

Additional considerations:

- Are there specific technical and economic feasibility considerations for conditions on the minimisation of releases of PFAS in the environment for "essential uses" where PFAS foams would be still needed?
- Capacity available, conditions required, efficiency of, human health/environmental safety and costs of disposal of existing PFAS foams (e.g. via incineration).

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2. **Essential uses and availability of alternatives**

- Do the alternatives impart the desired functionality and comply with the required performance criteria/standards? If not, what functionality is inadequate?
- Are there critical uses/applications of fire-fighting foams where PFAS CANNOT be adequately replaced by ANY alternatives? Are some sectors more advanced on substitution than others and why is that the case?
- Are there differences in required volumes of use or application methods between PFAS-based and fluorine-free foams? Do volumes differ depending on specific applications/conditions?
- What are the financial/economic implications of using fluorine-free alternatives (e.g. unit price, frequency of foam replacement, cost of new equipment)? Do costs differ depending on specific applications/uses?
- Are there any other alternatives (including technologies) still under development/testing phase, not already (widely) available on the market?

3. **Remediation costs and technologies**

- Which technologies are most commonly/likely applied for the remediation of soil and water contaminated by PFAS or alternative fire-fighting foams?
- What are the differences in remediation practices between PFAS-containing foams and fluorine free foams and between fire training exercises and true emergency responses?
- Are there cases where remediation is not necessary, not technically feasible or not economically viable?
- What approaches are used to manage regular run-off and storm-water run-off and what restrictions exist on discharge concentrations/volumes and treatment prior to discharge?
- Which additives, degradation-products or by-products of fire-fighting foams need to be considered, for both PFAS foams and alternatives?
- What are the current regulatory drivers to engage in remediation (e.g. permits for training activities and discharge, Water Framework Directive EQS for PFOS)?

4. **Current/ future market trends in PFAS-based and fluorine-free foams**

- Are the estimates of the tonnages of PFAS-based and fluorine-free fire-fighting foams placed on the EU market and used in different sectors (still) accurate?
- Are any further shifts in the market expected (e.g. increasing share of specific types of foams, changes in prices for certain foams, changes in use patterns)? If so, what?
- How can the current data gaps (revenues from sales, which PFAS and alternative substances are used the most in fire-fighting foam) be addressed?

The next section of this report covers the preliminary findings for this project, which will form the basis of the discussion during the workshop.

2. Preliminary findings of the project

2.1 Structure of this section

The remainder of this report covers the preliminary findings as follows:

- Sections 3-5 present the interim findings of the DG ENV study, i.e. the substance identification of fire-fighting foams, market analysis, and potential emissions to the environment during use
- Section 6 then focuses on the analysis of (fluorine-free) alternatives that is part of the ECHA study
- Section 7 gives further details of the next stages of the project and tasks that will be undertaken following the workshop
- Appendix A provides an overview of the written questionnaire consultation previously undertaken
- Appendix B gives a full list of the identified substances in both PFAS-based and fluorine-free foams

3. Task 1. Substance identification

3.1 Introduction

The objective of this task is to identify the PFAS (including long and short chain, their salts and precursors, intentionally used or as impurities) present in fire-fighting foams, the constituents of the fluorine-free fire-fighting foams and any non-PFAS fluorinated alternatives (if they exist).

Below the approach is briefly described (Section 3.2). Then, interim results are discussed in Section 3.3. This is carried out in separate sub-sections; first for alternatives to PFAS in fire-fighting foam that are fluorinated (but not based on PFAS), then for completely fluorine-free alternatives, and lastly for PFAS used in fire-fighting foams.

3.2 Approach

The substance identification was based on screening literature, regulatory documents and monitoring data using a specific set of search terms, as well as input from international experts. In addition to desktop research, ECHA identified substances used in fire-fighting foams based on a search of REACH registration dossiers and provided this data to the project team.

3.3 Interim results

In this substance identification process, three substance classes, that are/were used in firefighting foams, were considered: PFAS substances, fluorinated but not-PFAS alternatives and fluorine-free replacements. The main outcomes of this task are as follows:

- For PFAS substances, various carboxylic/sulfonic short- and long chain PFAS as well as a variety of fluorotelomers were identified. These substances differ in chain length and attached

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functional group and only a relatively small amount of these substances could be identified by CAS/EC number. Furthermore, other PFAS substances that do not belong to any of the PFAS-categories listed above were found.

- For fluorinated but not-PFAS alternatives, no substances were identfied in the literature review. Experts consulted as part of the study also cofirmed that these are not used.
- The fluorine-free replacements identfied can be grouped into four classes: hydrocarbons, detergents, siloxanes and proteins. For the latter two classes, the information gathered and the number of identified substances are relatively small. The use of siloxanes in firefighting foams is still under development. In contrast, a variety of hydrocarbons (around 24) and detergents (33) were identified, that are used as replacements for PFAS-substances.
- A list of all substances for which CAS/EC numbers could be identified is in 0. Market analysis (see follwing section) has confirmed that some of these substances are used, along with associated tonnages. However, for a large share of the tonnages of fire-fighting foams used, the associated substances could not be identified by name or CAS/EC number in the market analysis. Hence, for the other substances identified that cannot be associated with market data, it is not clear how commonly they are currently used in the EU.

In summary, a large number of diverse PFAS substances were identified that are used in firefighting foam. This could be an indication of extensive replacement chemistry, that was initiated due to industry and regulatory concerns about the potential health and environmental impacts of long-chain PFAS and more recently short-chain PFAS. However, the sheer amount of identified substances highlights the need for prioritisation of the identified substances as part of the later analysis.

4. Task 2. Market analysis

4.1 Introduction

The main aim of this task is to estimate the tonnages of fluorine-based and fluorine-free fire-fighting foams manufactured and placed on the market in the EU. The different functions (e.g. film-forming, surfactants, solvents) provided by different components of fire-fighting foams and the type of fires for which their use is recommended is also discussed. Below we briefly describe the approach before summarising interim results.

4.2 Approach

This task involved a combination of a targeted stakeholder consultation and a review of relevant literature and statistical sources:

- A literature review focused on keyword searches and a systematic review of information from key organisations in the field, including ECHA, UNEP, Emerging contaminants EU, foam manufacturers, relevant industry associations and others.
- A total of 22 stakeholders have contributed to the consultation to date[1]. The project team is currently in contact with several key stakeholders to fill data gaps.
- Relevant statistics providing quantities of production and trade of products in the EU have been screened, notably the Eurostat Prodcom database. However, the breakdown of the data is

[1] Correct as of 10 September 2019.

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not sufficiently detailed to distinguish specific types of fire-fighting foams (or even foams from other fire-fighting preparations). For that reason, these statistics are not used.

4.3 Interim results

PFAS in fire-fighting foams

Tonnages and values

Most of the data identified in the literature relates to amounts of PFOS or "PFOA-related compounds" and is several years old. However, these long chain PFAS have been increasingly (even completely in the case of PFOS) replaced by shorter chain PFAS or fluorine-free alternatives for use in fire-fighting foams, so these data are likely out of date or only reflect a small share of the current market.

According to data provided by Eurofeu, five foam manufacturers representing approximately 60-70% of the EU market purchase approximately 335 tonnes of fluorosurfactants per annum in the EU (2018 data). This data specifies 7 specific known fluoro-compounds and 3 unknown fluoro-compounds (see Table 4.1). They are used to produce fire-fighting foam concentrates or liquid ready-for-use agents (pre-fill for fixed firefighting systems and/or portable extinguishers). According to the same Eurofeu data, the concentration of the fluoro-compound in the fire-fighting foam concentrates range between 0.1% and 45%.

Table 4.1 Tonnage of fluorosurfactants purchased for the production of fire-fighting foams by manufacturers participating in the 2018 Eurofeu survey

Fluoro-compound	CAS number	Tonnes per year
1-Propanaminium,N-(carboxymethyl)-N,N-dimethyl-3-[[(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl)sulfonyl]amino]-,inner salt	34455-29-3	21.1
1-Propanaminium, 3-amino-N-(carboxymethyl)-N,N-dimethyl-N-[[(gamma-omega-perfluoro-C6-C16-alkyl)thio]acetyl] derives., inner salts	80475-32-7	17.2
2-methyl-2 - [(1-oxo-3 - [(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl) thio] propyl) amino] -1-propanesulfonic acid, sodium salt	62880-93-7	0.5
2-hydroxy-N,N,N-trimethyl-3-[(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl)thio]-1-Propanaminium, chloride (1:1)	88992-45-4	0.2
2-Propenamide, telomer with 4-[(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl)thio]-1-butanethiol)	unknown	0.2
2-Propenoic acid, telomer with 2-propenamide and 4-[(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl)thio]-1-butanethiol, sodium salt	unknown	0.3
2-Propenamide, telomer with 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluoro-1-octanethiol	76830-12-1	0.9
unknown C-6 fluorinated substances	unknown	17.1
unknown 1	unknown	138.6
unknown 2	unknown	138.6

Source: Data provided to the authors by Eurofeu.

Additional data provided as part of the consultation (not included in the above tonnage estimates) indicates that in excess of 550,000 litres of foam concentrate based on PFAS substances with the CAS numbers 34455-29-3 (a substance whose use was also identified by the Eurofeu data in the table above) and 27619-97-2 (a new substance whose use was not identified by the Eurofeu data in the table above) are sold in the EU per year. At the time of writing, Eurofeu was in the process of collecting the most recent data on the overall tonnage – based on its members' annual EU sales of PFAS-based (and fluorine-free) fire-fighting foams, including a breakdown by sector, which will be available shortly.

The consultation suggests prices for PFAS based fire-fighting foams ranges from €2.0 to €30 per litre for concentrates. Some consultation responses suggest that generally speaking, foams providing a higher performance often contain a higher concentration of PFAS which is associated with a higher cost.

In conclusion, there are data gaps around which PFAS substances are most frequently used in fire-fighting foams as well as the tonnages of PFAS-based foams used and associated revenues (given the large range of prices indicated above), which we propose to discuss at this workshop. Some of these data gaps will be addressed by new data currently being collected by Eurofeu.

Functions provided in the foams and types of fires the foams are used for

The main function of the PFAS contained in the foam is to act as a surfactant, i.e. to form a film over the burning liquid surface in order to prevent flammable gases from being released. This is particularly relevant for fire involving flammable liquids (Class B fires). They can be applied both with mobile and semi-stationary equipment.

According to the consultation, the majority of PFAS-based fire-fighting foams are used in the chemicals/petrochemicals sectors. A significant share is also used in marine applications, airports and municipal fire-fighting. Other consultation responses also indicated uses in the waste sector and railways. Ready for use products (e.g. fire-extinguishers) are expected to account for only a relatively small amount of PFAS-based foam usage. As mentioned above, data on the use by sector is currently being collected by Eurofeu.

Three users from the largest user sector, chemicals/petrochemicals, have specified in the consultation that foams are used for spills, accidents and function tests in process plant or alcohol fires and training (e.g. training exercises on large hydrocarbon fires). Some users have provided additional information on the amount of foam applied per use and the frequency of use. One user employs less than 5 tonnes in each instance of use. Another user states that, in 75% of cases, fires are extinguished with less than 400 litres of foam concentrate, which suggests there can be large range in terms of the tonnage used per instance, depending on the application. Use can in some cases occur frequently, with one user suggesting they typically employ it 100 days a year.

Fluorine-free fire-fighting foams

Tonnages and values

As discussed above, at the time of writing Eurofeu were collecting additional data on the tonnage of fluorine-free foams sold by their members in the EU. They expect volumes of fluorine-free foam to have increased significantly in recent years with up to two-thirds of foams now produced being fluorine-free.

Additional manufacturers that have been consulted but are not expected to be included in the Eurofeu data, stated they sell around 880,000 litres of hydrocarbon-based surfactant foam concentrates in the EU per year. These are not AFFF, i.e. they do not form a film on the burning surface, but instead create a stable blanket of foam to fulfil a similar function.

The consultation suggests prices for fluorine-free foams ranges from €0.7 to €10 per litre, with most values above €2 per litre. Although this is lower than the range of prices some consultation responses indicated for PFAS-based foams (see above), some respondents suggested that fluorine-free foams are around 50% more expensive than comparable foams containing fluorine.

Functions provided in the foams and types of fires the foams are used for

The PFAS-free fire-fighting foams considered in this analysis are specifically those that can potentially be used as alternatives to the PFAS-based foams. As such, they are used in the same applications. The consultation responses specifically indicated that PFAS-free alternatives are currently used for training, process fires, alcohol fires and fuel fires, as well as for testing proportioning systems and are applied both with fixed and mobile equipment. Any potential differences in the performance in these applications between fluorine and non-fluorine foams (including whether there are critical applications where fluorine-free foams are not considered feasible alternatives) will be analysed in more detail in the analysis of alternatives (see Section **Error! Reference source not found.**).

The substance identification (Task 1) identified the following groups of substances that PFAS-free fire-fighting foams are based on: hydrocarbons, siloxanes, protein foams, detergents. All of these groups largely mimic the function of fluoro-surfactants in the PFAS-based fire-fighting foams, for instance hydrocarbon foams use hydrocarbon surfactants[2], siloxanes are also primarily used in fire-fighting foams to function as surfactants[3] and detergents are by definition surfactants.

Summary of results

The table below summarises some of the key results that have been discussed in more detail above.

Table 4.2 Summary of key preliminary market analysis results

	PFAS-based fire-fighting foams	Fluorine-free alternatives
Tonnage of foam used	Data gap. New data currently being collected by Eurofeu.	Data gap. New data currently being collected by Eurofeu.
Tonnage by substance / Substances most commonly used	>335 tonnes of fluoro-surfactants used annually in EU. Breakdown of tonnage for 8 substances available (see Table 4.1 and directly below that table), but for majority of tonnage the substances are not known.	No quantitative data.
Breakdown of tonnage by use sector	Data gap. New data currently being collected by Eurofeu.	Data gap. New data currently being collected by Eurofeu.
Revenues	Data gap.	Data gap.
Prices	€2.0 to €30 per litre	€0.7 to €10 per litre
Functions provided and types of fires used for	Surfactant to form a film over the burning surface. Particularly relevant for fire involving flammable liquids (Class B fires).	Those fluorine-free foams considered alternatives to PFAS-based foams in principle provide the same (or a similar) function.

[2] See for example: https://www.fomtec.com/fluorine-free/category38.html or https://www.chemguard.com/about-us/documents-library/documents/Martin2009ReebokEcoguardpresentation2010-10-11.pdf.
[3] See for example: https://www.nfpa.org/-/media/Files/News-and-Research/Resources/Research-Foundation/Symposia/2016-SUPDET/2016-Papers/SUPDET2016Hetzer.ashx?la=en.

	PFAS-based fire-fighting foams	Fluorine-free alternatives
	Consultation suggests it is used both in training and true emergency responses.	Consultation suggests it is used both in training and true emergency responses, but in some cases in training only.
Trends	Rapid shift from PFAS towards fluorine-free foam in recent years, expected to continue.	

4.4 Remaining work required to complete

The market data presented above requires further validation and discussion. In particular, the following information is needed to complete the work:

- Total tonnage of PFAS-containing foams and fluorine-free foams used/sold in the EU with breakdown by user sectors (data is currently being collected)
- Revenues from sales of PFAS-containing foams and fluorine-free foams in the EU
- Additional information on which PFAS and alternative substances are used the most in fire-fighting foams

Workshop breakout group 4 will focus on: Current/ future market trends in PFAS-based and fluorine-free foams

- Are the estimates of the tonnages of PFAS-based and fluorine-free fire-fighting foams placed on the EU market and used in different sectors (still) accurate?
- Are any further shifts in the market expected (e.g. increasing share of specific types of foams, changes in prices for certain foams, changes in use patterns)?
- How can the current data gaps (revenues from sales, which PFAS and alternative substances are used the most in fire-fighting foam) be addressed?

5. Task 3. Assessment of the emissions and hazard of fluorine-free foams

5.1 Introduction

The focus of this task is to estimate the emissions of PFAS and of the constituents of the alternative fluorine-free fire-fighting foams to the environment. This is broken down by environmental compartment (Aquatic environment (marine and inland waters), terrestrial environment and the possible uptake by humans via the consumption of food and water. Task 3 also assesses the hazard (and risk, to the extent possible) to human health, the environmental and humans via the environment of the fluorine-free foams and any non-PFAS fluorinated alternatives, if they exist. The development of emission estimates is expected to follow the relevant guidance provided by ECHA[4] and will be conducted after the workshop.

[4] See available guidance documents at: https://echa.europa.eu/guidance-documents/guidance-on-reach

5.2 Approach

Based on the discussions with the Commission we have followed the ECHA guidance to develop a basic source-flow model which utilises the data from Task 1 and 2. A source-flow approach tracks the flow of a material across its lifespan and the key points where releases to environment occurs. For the current study we have assumed that the lifecycle begins with the formulation of fire-fighting foam concentrates[5]. It then proceeds to storage of concentrates, use for testing and training, use in live incidents, and management of wastes. This final stage includes both end of life stockpiles which have expired, and wastes generated during use (i.e. wastewater from fire runoff).

We have created a model which tracks the flow of material and releases at key points. In order to do this, we have needed to make key assumptions about usage and factors effecting releases. Tables 5.1 and 5.2 provide details of the key assumptions that will be applied to market data for the source-flow approach.

We would very much welcome your feedback on these assumptions, particularly if you feel they are inaccurate. Note that the market split is expected to be adjusted to reflect new market data currently being collected (see Section 4).

Table 5.1 Overview of market splits and usage rates[6]

Industry sectors	Market split as %	Annual usage rates (against stockpiles held)	Proportion used for training and testing	Proportion used for live incidents
Military	29%	7%	93%	7%
Civil Aviation	16%	12%	93%	7%
Municipal fire services	14%	7%	7%	93%
Petroleum refineries	20%	12%	93%	7%
Petrochemical manufacturing	21%	7%	93%	7%

Table 5.2 Other key assumptions used within the source flow approach

Life-cycle stage and processes	Assumptions
Formulation of fire-fighting foam concentrates using fluorinated surfactants	Emissions to: • air 2.5% of surfactant used; • wastewater 2% of surfactant used; and • land 0.01% of surfactant used.[7]
Storage of fire-fighting foam concentrates prior to use	Emissions related to leaks and spillages. 1% of stockpiles held in storage annually (expert judgement based on consultation feedback)

[5] The surfactants used within fire-fighting foam concentrates may have many applications, and therefore to maintain a fair and level playing field the manufacture of the surfactants themselves is excluded from the current source-flow approach on the basis that manufacture may cover more than just use in fire-fighting applications.
[6] Based on a combination of the OECD exposure scenario data and Brooke et al (2004) 'Environmental risk evaluation report for PFOS' – Report for the UK Environment Agency
[7] Based on data taken from the Annex XV restriction dossier for PFOA, its salts and PFOA-related compounds

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Life-cycle stage and processes	Assumptions
Efficacy of capture and storage devices (such as bunding) during testing / training sessions.	Efficacy assumed to be 97% - i.e. 97% of all foam used is captured and retained for destruction. 3% is lost to wastewater systems. (expert judgement) This efficacy rate is applied to all industry sectors without further specialisation.
Efficacy of capture and storage devices (such as bunding) during live incidents.	Efficacy assumed to be 0%. I.e. during live incidents 100% will be lost to environment. Assumed to be 50% land and 50% surface water[8].
Efficacy of waste incineration for destruction of surfactants. This could be end of life stockpiles, or wastewater captured during testing / training.	Assumed efficacy of incineration processes 99%. (expert judgement). This value is applied to both fluorinated and non-fluorinated foams.
Efficacy of waste water treatment processes for fluorinated fire-fighting foams.	Based on review of efficacy against PFOS and PFOA we assume that wastewater treatment processes will be 50% effective. i.e. 50% of the surfactant committed to wastewater treatment remains undegraded and is released to surface water / sewage sludge based on partitioning.
Efficacy of waste water treatment processes for non-fluorinated fire-fighting foams.	Based on expert judgement assume wastewater treatment processes will be 80% effective. i.e. 20% of the surfactant committed to wastewater treatment remains undegraded and is released to surface water / sewage sludge based on partitioning. We assume that WWTPs will be more effective against non-fluorinated alternatives, as the main alternatives appear to be hydrocarbon based and WWTPs are typically geared to destroy these kinds of compounds.

5.3 Remaining work required to complete

The outputs of Task 1 identify approximately 70 substances used within PFAS-based and fluorine-free foam products. Realistically, based on the available data this is too many to accurately calculate emission estimates for. We therefore propose a screening step based on quantities in use and hazards of the substances (as a secondary parameter). Based on this full emission estimates for the most common and hazardous substances will pass to the emission estimate phase. Therefore, the completion of Task 3 will require the following steps:

- Further refinement of the source-flow approach following discussion with stakeholders, the Commission/ECHA and review of the assumptions within the model.
- Further review of the 'use' profiles stage of the life-cycle to assess what further elaboration and refinement can be made beyond 'training' and 'live' use. Again, this will be completed with discussion and input from the Commission/ECHA.
- Development of emission estimates for the screened set of substances/products to further compare the quantities of PFAS vs fluorine-free alternatives emitted.
- Based on hazard and persistence data together with primary environmental compartment of release, an assessment will be made to identify which substances/products may be of greatest concern.

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- Further consideration will also be given - based on types of use together with emission outputs – to identify substances/products that may represent a risk for ground contamination from multiple uses of the same substances/products at the same sites.

6. Task 4: Analysis of alternatives (AoA) to PFAS-based fire-fighting foams

6.1 Introduction

The objective of this task is to assess the technical feasibility, economic feasibility, and availability of alternatives to PFAS-based fire-fighting foams, in order to feed into the pre-RMOA and (pre) Annex XV restriction dossier report. At this stage of the project we have completed the information gathering for approximately half of the ~170 alternative products identified in Task 1 (Substance ID) and are supplementing this with data recently gained from the consultation responses on alternative products in use in the EU.

6.2 Approach

The AoA will focus on alternative products or techniques that could fulfil the required function. Typically, the assessment identifies a potential long list of alternatives, before evaluating a more limited number in greater detail. Information on fluorine-free alternatives was obtained by conducting a wide review of the literature and market analysis of fluorine-free products currently manufactured and available in the EU. Findings have been supplemented with consultation responses on 'in-use' alternatives and will be further added to with information from the stakeholder workshop.

6.3 Interim results

The total number of fluorine-free alternative foam products identified in Task 1 (Substance ID) was ~170, produced by 38 different companies globally. Similar substances are being used to make these across the different companies/products. However, this list does not tell us exactly which products are currently being used in the EU, so this has been supplemented with information from the consultation responses on in-use alternatives.

Step 1 – Information gathering on fluorine-free products

Our first step was a literature review of Safety Data Sheets (SDS), publications, reports and product data sheets for each of these fluorine-free products to extract data on technical/ economic feasibility and availability. To date we have completed the literature search for 70 products manufactured by 11 companies. Based on these initial results the following patterns emerge for the fluorine-free alternatives.

The **sectors/uses covered** by the fluorine-free alternatives evaluated to date show that:

- The alternative products include use across all fire-fighting sectors, i.e. aviation, oil and gas, military and domestic fire-fighting. For these sectors, both emergency response and training foams are available.
- According to the manufacturers' specifications, fluorine-free foams are available for class A and B fires. Some products, e.g. Expandol from Angus Fire or Ecopol from Bio-Ex are specified for use for both class A and B fires depending on concentration and application method.

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- Fluorine-free foams are either recommended as low, medium or high expansion foams, or the same product can be used with different expansion ratios depending on use concentration and equipment, e.g. the H-930 synthetic multiexpansion foam concentrates from Auxquimia.
- In some literature reviews (e.g. an IPEN position report by Allcorn et al. 2018), the availability of fluorine-free foams as viable alternatives to PFAS containing foams is emphasised for almost all sectors, even for critical uses such as aeroplane rescue.
- In the IPEN (2019) report[8] on fluorine-free alternatives, a number of European airports (including Dortmund, Stuttgart, London Heathrow, London Gatwick, Edinburgh, Manchester, London City, Leeds-Bradford, and Copenhagen) are noted to have transitioned to fluorine-free foams. It is also reported that a number of companies across the oil and gas and petrochemicals industries (for example BP, ExxonMobil, Total, Caltex, Equinor, Gazprom, Statoil, BASF, Chemours, AkzoNobel, Stena Line, and Pfizer) are also using fluorine-free foams.
- In addition to the direct information from the stakeholder questionnaire (e.g. from Heathrow airport, Copenhagen airport, Equinor), input from organisations dedicated to fire safety training, also indicated fluorine-free foams are used for these activities.
- The only use where the efficiency of viable fluorine-free foam alternatives is still debated, is for liquid fuel fires of large atmospheric storage tanks. Combatting these fires requires foams capable of flowing on large burning liquid surfaces and sealing against hot metal surfaces to prevent reignition. The recently published results of LASTFIRE[9] indicate that performance of some fluorine-free foams is comparable to PFAS-based foams and can meet minimum extinguishment requirements, however.

The main **information gaps** identified in the step 1 literature review are:

- Information on both current EU use and technical performance of specific fluorine-free foams products in comparison with Aqueous Film Forming Foam (AFFF), Fluoroprotein foam (FP) and Film-forming fluoroprotein (FFFP) is limited in the published literature.
- The comparison of performance parameters is challenging as this depends on application rate, method and equipment and are interdependent. Such details are typically not listed alongside the result of performance tests.
- Information on market, costs, availability and economic feasibility within the datasheets and published literature are limited, and available information in articles and position papers can be contradictory.

Step 2 Consultation responses

Information gathered on fluorine-free alternative products from SDS and the literature review is currently being supplemented with the stakeholder consultation responses received to date. This acts as the second step in the analysis of alternatives.

- In terms of availability of alternatives, the responses received identified, ~80 specific products currently in use. This list will be used to further prioritise and inform the list of those considered for more in-depth analysis
- Based on the survey responses received, the alternative foam products identified by the producers and users include those marketed by Bio-ex (e.g. ECOPOL, BIO FOR, BIO FOAM, BIO

[8] IPEN 2019/Stockholm Convention COP-9 White Paper, The Global PFAS Problem: Fluorine-Free Alternatives As Solutions, https://ipen.org/sites/default/files/documents/the_global_pfas_problem-v1_5_final_18_april.pdf
[9] http://www.lastfire.co.uk/default.aspx?ReturnUrl=%2f

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T), Solberg (e.g. RE-HEALING™ foams), Dr. Sthamer (e.g. Moussol ; Sthamex F-6 ; Sthamex F-15), Auxquimia (e.g. EE-3).

- Furthermore, the IPEN (2019) report highlights a non-exhaustive list of fluorine-free products and suppliers including Angus (Respondol); Bio-Ex (Ecopol Premium); Dr Sthamer (Moussol-FF); Orchidee (BlueFoam); 3F (Freedol); Solberg (RF6, RF3x6ATC, RF1 series); Fomtec (Enviro); Tyco (Skum3x3); National Foam (Universal F3 Green); Auxquinia (Unipol); and VSFocum (Silvara).
- In terms of the chemical identity of alternative products, in most cases, where alternative foam products were named, the specific chemical components were either not known or not divulged (e.g. citing trade secrets).
- In terms of differences in foam volumes required to achieve comparable/acceptable functionality between PFAS and FF foams, most responses suggest there is no difference, however, one user in the oil/petrochemicals sector suggests the alternative (FF) foams required 30-50% more by volume. It is not possible to draw definitive conclusions from this small sample size. A number of respondents identified and discussed perceived critical uses or applications of foams where alternatives are lacking and PFAS cannot be replaced.

The stakeholder consultation questionnaire responses have yielded useful information. However, a number of **key data gaps** have been identified from the responses to the questionnaire:

- The specific chemical identity of foam products identified in the responses is not always available/divulged, this makes the comparison of risk posed (to the environment) compared to traditional foams difficult for a number of products.
- Limited data was received on the costs of replacing equipment associated with switching to alternative foams. This makes the assessment of economic feasibility of alternatives more difficult.
- Limited quantitative data was provided on the potential savings associated with switching to alternatives. This makes the overall assessment of economic feasibility of alternatives more challenging.

6.4 Remaining work required to complete

From the extensive list of fluorine-free products, we will shortlist a maximum of 15 key alternative fluorine-free products that are most widely used in the EU and which we judge the most viable/realistic. Following the workshop, we will fully investigate their feasibility, cost and availability to replace PFAS-containing foams for different uses (sectors/types of fire). This will include exploring whether fluorine-free alternatives can fully replace the current PFAS-containing foams for all different uses. We aim to identify at least one available technically/ economically feasible alternative (if it exists) for each use.

An initial list of 25-30 foam products to be included is detailed below. Feedback from workshop participants will be sought to finalise this list and establish those products most commonly used in the EU.

Product	Manufacturer/Supplier
Sthamex F-15	Dr. Sthamer
Sthamex F-6	Dr. Sthamer
Expandol LT	Angus fire
Forexpan	Angus fire

Product	Manufacturer/Supplier
Respondol	Angus fire
Sthamex F-6	Dr. Sthamer
Sthamex F-15	Dr. Sthamer
Moussol FF 3x6	Dr. Sthamer
Übungsschaummittel-N	Dr. Sthamer
Bluefoam 3x3	Orchidee
Bluefoam 1x3	Orchidee
Bluefoam 3x6	Orchidee
Bluefoam 6x6	Orchidee
Re-Healing Foam RF-H+	Solberg
Re-Healing TF	Solberg
Re-Healing Foam RF3x3 FP ATC	Solberg
Re-Healing Foam RF 3x6 FP ATC	
Re-Healing Foam RF1 1%	Solberg
Re-Healing Foam RF1-S 1%	Solberg
Re-Healing Foam RF3 3%	Solberg
Re-Healing Foam RF3x6 ATC	Solberg
Re-Healing Foam RF-MB	Solberg
Re-Healing Foam RF6 6% **ECOPOL**	Solberg Bio-ex
BIO FOR	Bio-ex
BIO FOAM	Bio-ex
BIO T3 and BIO T6	Bio-ex
EE-3 Newtonian Training foam	Auxquimia
Unipol	Auxquinia
ARC 3x3	Fomtec
Environ	Fomtec
FREEFOR SF	3F Company

The final stage in the analysis of alternatives will draw all the information together and include a detailed analysis of technical feasibility, economic feasibility and availability of all shortlisted alternatives. Furthermore, the information will be used in the later socio-economic analysis which examines the impacts of an EU-wide restriction or total ban of the use of PFAS-containing fire-fighting foam.

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Workshop breakout group 2 will focus on: Essential uses and availability of alternatives

- Do the alternatives impart the desired functionality and comply with the required performance criteria/standards for each type of use?
- Are there critical uses/applications of fire-fighting foams where PFAS CANNOT be adequately replaced by ANY alternatives? Are some sectors more advanced on substitution than others?
- Are there differences in required volumes of use or application methods between PFAS-based and fluorine-free foams?
- What are the financial/economic implications of using fluorine-free alternatives? e.g. unit price, frequency of foam replacement, cost of new equipment.
- Are there any other alternatives still under development/testing phase, not already (widely) available on the market?
- What are the hazards of the alternative foams? Could foam manufacturers generate comprehensive hazard assessments on their products (themselves or through third parties) and publish non-confidential versions of the outcome (i.e. without revealing the exact composition)?

7. Next steps and remaining tasks

7.1 Assessment of the remediation costs

The results from Task 2 (market/use information) and Task 3 (estimates of foam emissions) will be used to develop remediation scenarios following the workshop. Additional research will then be undertaken to identify the most likely remediation technology applications and associated costs for each scenario.

Workshop breakout group 3 will focus on: Remediation costs and technologies

- Which technologies are most commonly/likely applied for the remediation of soil and water contaminated by PFAS or alternative fire-fighting foams?
- Are there cases where remediation is not necessary, not technically feasible or not economically viable?
- Which additives, degradation-products or by-products of fire-fighting foams need to be considered. for both PFAS foams and alternatives?

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7.2 Summary of the information in the form of a Risk management option analysis (pre-RMOA)

Several questions in the consultation specifically addressed the assessment and design of potential risk management options. The questions related to the potential impacts of:

- different transition periods for phasing out PFAS in fire-fighting foams;
- different threshold concentrations of PFAS (i.e. impurity levels) in fire-fighting foams once any potential future regulation is in place; and
- restrictions on new PFAS-containing fire-fighting foam products entering the market only versus restrictions on both new PFAS-containing foam products and those already in use in existing systems.

Several respondents have provided responses to these questions, providing a range of different views and suggestions. This included calls for considering exemptions for high performing C6 PFAS foams, a clearly defined set of uses under defined conditions of use. Some suggested that in order to allow users to transition smoothly and cost-effectively, transition periods and threshold concentrations should be chosen with this in mind, and a restriction should cover only new products. Others noted that a successful transition has already been achieved in many cases so that the impacts of a strict restriction would be manageable, and that the continued use of PFAS-based foams in existing systems could lead to issues with immediate refill requirements during incidents.

We seek to further clarify and discuss these issues during the workshop. This work will furthermore entail summarising all the information from the previous tasks of both the DG ENV study and the ECHA study, following the structure of a RMOA ("pre-RMOA").

Workshop breakout group 1 will focus on: Different Risk Management Options (RMOs)

What are the potential impacts of:

- different transition periods for phasing out PFAS in firefighting foams?
- different threshold concentrations of PFAS (i.e. impurity levels) in firefighting foams once the potential future regulation is in place? (e.g. in relation with the cost to clean up the installation to comply with the PFAS impurity threshold)
- restrictions on new PFAS-containing firefighting foam products entering the market only vs restrictions on both new PFAS-containing foam products and those already in use in existing systems?

Additional considerations:

- Technical and economic feasibility of conditions on the minimisation of releases of PFAS in the environment for "essential uses" where PFAS foams would be still needed.
- Capacity available, conditions, efficiency, human health/environmental safety and costs of disposal of existing PFAS foams (e.g. via incineration).

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7.3 Pre-Annex XV restriction dossier

This task of the project will entail presenting all information developed in both the DG ENV study and the ECHA study (as well as information on the hazard of PFAS developed by the PFAS Working Group, if available within the timescales of this project) in the form of an Annex XV dossier. Work on this task will begin after the workshop.

7.4 Socio-Economic Analysis

This task will assess the socio-economic impacts of an EU-wide restriction or total ban of the use of PFAS-containing fire-fighting foam to inform the pre-RMOA and Annex XV dossier report.

The restriction scenarios that we will consider are:

1) Restriction (ban) on the **placing on the market** of PFAS-based FFF. The use of legacy foams, i.e. foams already in stock at producers' or users' sites, is still permitted.

2) Restriction (ban) on the **placing on the market and the use** of PFAS-based FFF. The legacy foams, i.e. foams already in stock at producers' or users' sites, should be disposed of safely.

As noted above, the potential impacts (costs and benefits) of these types of restrictions will be discussed in workshop breakout group 1.

Appendix A Outcomes of the Questionnaire consultation exercise

Introduction

This appendix presents the results of the consultation undertaken to support all tasks across both the DG ENV study and the ECHA study. Task-specific results have been presented in the main body of the report.

Effective engagement with key stakeholders from across the fire-fighting foam sector, particularly the manufacturers and users of the foams, is critically important in the data collection process for this work. The consultation covered all the relevant sectors and backgrounds across the fire-fighting foam supply chain, as well as regulators, researchers and special interest groups. The consultation therefore aimed to target the following stakeholders:

- Foam manufacturers / suppliers;
- Users of foams in major sectors (including airports, oil and gas platforms, chemical plants, ports, railways);
- Key trade associations;
- International organisations;
- National-level authorities and agencies;
- Academics and R+D (especially those involved in developing alternative foam products);
- Key NGOs and interest groups.

Approach

The written questionnaire was sent directly via email to ~40 targeted stakeholders. In a number of cases, stakeholders forwarded the consultation document to other stakeholders (e.g. associations' member companies). A consultation period of ~6 weeks was allowed, for the completion of the stakeholder questionnaire.

Interim results

A total of 22 written responses to the questionnaire have been received to date[10]. Of the different types of stakeholder targeted, the most responses were from users/industry (12), with smaller numbers of responses from individual manufacturers (2), authorities/agencies (4), industry associations (2), and 'other' stakeholders (2) e.g. academic/testing/training professionals. The responses from the users of foams cover all the main sectors targeted (airports, oil refineries/storage, chemicals, petrochemicals, and rail).

Stakeholders also provided previously published data or reports in addition to, or instead of, the questionnaire. This included reports and analyses from national authorities[11], research and testing information[12], and special interest groups[13].

The consultation has yielded useful information such as:

- Identifying some of the key foam products containing PFAS on the EU market, and non-PFAS alternatives actually used in key sectors;

[10] Correct as of 10 September 2019.
[11] KEMI (2015) Chemical Analysis of Selected Fire-fighting Foams on the Swedish Market 2014
[12] Published testing data, as provided by LASTFIRE: www.lastfire.co.uk/
[13] IPEN (2019) The Global PFAS Problem: Fluorine-Free Alternatives as Solutions, https://ipen.org/documents/global-pfas-problem-fluorine-free-alternatives-solutions

- Identifying specific PFAS, precursors and impurities present in some foam products;
- The functionality of PFAS-containing foams useful to the major users of foams and reasons why products containing PFAS have not been fully replaced;
- Volumes of production and use, and unit price for a small number of individual products;
- Information on available alternatives, including specific products on the market in the EU, the type and sector of use, their availability, volumes of sale and use, their perceived technical feasibility and economic feasibility (see Section 3, Task 1 analysis of alternatives);
- Details of fire-fighting foam use e.g. volumes, frequency;
- Some details of methods, regulations, and guidelines in place to prevent release to the environment;
- Some information on the methods/approach to disposal of individual foam products;
- Preliminary stakeholder opinions and feedback on different potential regulatory risk management options were provided;

Data gaps

The level of detail provided by respondents varied between questions. For some sections, a number of information gaps, where the level of detail provided by respondents was less substantial, were identified. A brief summary of the key remaining data gaps identified, based on the consultation responses in each section is provided below:

- **Chemical identity, functionality of PFAS in fire-fighting foams**
  - No breakdown of use/sales of PFAS-containing foams and fluorine-free foams by user sectors in the EU;
  - No revenues from sales of PFAS-containing foams and fluorine-free foams in the EU;
  - A relatively small number of specific products are identified; based on a relatively small sample size of stakeholder responses;
  - Few responses have been received on trends and drivers on foam production and sales.
- **Alternatives to PFAS in fire-fighting foams (as discussed in Section** Error! Reference source not found.**)**
  - Information on EU-level production and use is lacking from the relatively small number of responses;
  - The specific chemical identity of foam products identified in the responses is not always available/divulged;
  - Limited data was received on the costs of replacing equipment associated with switching to alternative foams;
  - Limited quantitative data was provided on the potential savings associated with switching to alternatives.
- **Foam use and environmental emissions**
  - Limited data on volume and frequency of use of foams was received, based on a relatively small sample size of responses;

- Limited data was provided on foam collection for incineration or WWT;
- Limited data was provided on the methods and costs of foam disposal;
- Limited data was received on the levels of release to terrestrial and aquatic environment.

wood.

Appendix B Full list of identified substances

FFF (fluorine-free foams)

The following substance groups are frequently named in the literature as potential alternatives to PFAS in fire-fighting foams:

- Hydrocarbons
- Detergents
- Siloxanes
- Protein foams

In the following table, the identified substances are presented based on this grouping.

Table B.1 Identified hydrocarbons (identified by CAS) incl. CAS/EC identifier, the substance name, chemical group and the supplier and/or product name

CAS	EC	Substance name	Chemical group	Supplier and Product Name
500-344-6	157627-94-6	Alcohols, C10-16, ethoxylated, sulfates, triethanolammonium salts	Alcohols	Identified by ECHA
939-523-2		Alcohols, C8-10, ethoxylated, sulfates, sodium salts	Alcohols	Identified by ECHA
112-53-8	203-982-0	1-Dodecanol	Alcohols	Respondol ATF 3-6%: Angus Fire (Angus International: Angus Fire, National Foam and Eau et Feu.) LS xMax: Dafo Fomtec AB STHAMEX® 2% F6 Multi-purpose detergent foam: Dr Sthamer STHAMEX-SV/HT 1% F-5 #9142: Dr Sthamer
112-72-1	204-000-3	Tetradecanol	Alcohols	Respondol ATF 3-6%: Angus Fire (Angus International: Angus Fire, National Foam and Eau et Feu.) LS xMax: Dafo Fomtec AB STHAMEX® 2% F6 Multi-purpose detergent foam: Dr Sthamer STHAMEX-SV/HT 1% F-5 #9142: Dr Sthamer
160901-27-9	500-464-9	Alcohols, C9-11, ethoxylated, sulphates, ammonium salts	Alcohols	OneSeven of Germany GmbH. OneSeven Foam Concentrate Class A
67762-19-0	500-172-1	Alcohols, C10-16, ethoxylated, sulfates, ammonium salts	Alcohols	Kempartner AB: Meteor Allround Ma-13
67762-41-8	272-490-6	tetradecan-1-ol	Alcohols	Angus Fire: Expandol (aka Expandol 1-3), Expandol LT (aka Expanol 1-3LT)
68131-39-5	500-195-7	Alcohols, C12-15, ethoxylated	Alcohols	Verde Environmental Inc (Micro Blaze): Micro-Blaze Out
266-929-0	67701-05-7	Fatty acids, C8-18 and C18-unsatd.	Fatty Acid/oil	Identified by ECHA
11138-66-2	234-394-2	Xanthan gum	Gum	Auxquimia: Phos-Chek 3×6 Fluorine-free (aka UNIPOL-FF 3/6); Phos-Chek Training Foam 140

CAS	EC	Substance name	Chemical group	Supplier and Product Name
				Dr Sthamer: Moussol-FF® 3/6 FireRein: Eco-Gel Kempartner AB: Unifoam Bio Yellow Verde Environmental Inc (Micro Blaze) : Micro-Blaze Out
9000-30-0	232-536-8	Cyamopsis gum; Cyanopsis tetragonoloba	Gum	FireRein: Eco-Gel
9005-25-8	232-679-6	Starch	Hydrocarbon	Solberg: US20080196908
120962-03-0	601-748-6	Canola Oil	Oil	Eco-Gel; FireRein
25322-68-3	500-038-2	Poly(oxy-1,2-ethanediyl),α-hydro-ω-hydroxy- Ethane-1,2-diol, ethoxylated	Polyethylene glycol	Dafo Fomtec AB: Fomtec AFFF 1% F, Fomtec AFFF 3% S, Fomtec AFFF 3%
27252-80-8	608-068-9	ALLYLOXY(POLYETHYLENE OXIDE), METHYL ETHER (9-12 EO)	Polyethylene glycol	1% AFFF Denko 3% AFFF Denko 6% AFFF Denko Alcohol AFFF 3% - 6% Single or Double Strength Denko
32612-48-9	608-760-0	Poly(oxy-1,2-ethanediyl), α-sulfo-ω-(dodecyloxy)-, ammonium salt (1:1)	Polyethylene glycol	Orchidee Fire: Orchidex BlueFoam 3x3
73665-22-2	616-006-7	Poly(oxy- 1,2-ethanediyl), .alpha.-sulfo-.omega.-hydroxy-C6-10-alkyl ethers, sodium salts	Polyethylene glycol	Dr Sthamer: STHAMEX® 2% F6 Multi-purpose detergent foam, STHAMEX® 3% F6 Multi-purpose detergent foam, STHAMEX® K 1% F-15 #9143,STHAMEX-SV/HT 1% F-5 #9142, TRAINING FOAM-N 1% F-0 #9141
96130-61-9	619-194-9	Poly(oxy-1,2-ethanediyl), α-sulfo-ω-hydroxy-, C9-11-alkyl ethers, sodium salts	Polyethylene glycol	Dafo Brand AB: ARC Miljö Dafo Fomtec AB: Fomtec AFFF 1% A, Fomtec AFFF 1% F, Fomtec AFFF 1% Plus, Fomtec AFFF 1% Ultra LT, Fomtec AFFF 3%, Fomtec AFFF 3%ICAO, Fomtec AFFF 3% S, , Fomtec A-skum
308-766-0	98283-67-1	undecyl glucoside	Sugar	Identified by ECHA
439-070-6	439-070-6	(2R,3R,4S,5S)-2,3,4,5-tetrahydroxyhexanal (2R,3S,4R,5R)-2,3,4,5,6-pentahydroxyhexanal (2S,3S,4S,5R)-2,3,4,5-tetrahydroxy-6-oxohexanoic acid acetic acid calcium dihydride hydrate magnesium dihydride potassium hydride sodium hydride	Sugar	Identified by ECHA
110615-47-9	600-975-8	Alkylpolyglycoside C10-16	Sugar	Orchidee Fire: Orchidex BlueFoam 3x3
54549-25-6	259-218-1	(3R,4S,5S,6R)-2-(decyloxy)-6-(hydroxymethyl)oxane-3,4,5-triol	Sugar	Unifoam Bio Yellow

CAS	EC	Substance name	Chemical group	Supplier and Product Name
68515-73-1	500-220-1	Alkyl polyglucoside	Sugar	Dafo Brand AB: ARC Miljö Dafo Fomtec AB: Enviro 3x3 Plus, Enviro 3x3 Ultra, Enviro 3x6 Plus, Environ 6x6 Plus, LS aMax, MB -20, Trainer E-lite, Fomtec AFFF 1% A, Fomtec AFFF 1% F, Fomtec AFFF 1% Plus, Fomtec AFFF 1% Ultra LT, Fomtec AFFF 3% ICAO, Fomtec AFFF 3% S, Fomtec AFFF 3% OneSeven of Germany GmbH: OneSeven ® Foam Concentrate Class B-AFFF vs FOCUM: Silvara APC 3x6
na	917-341-4	AAlkyl polyglucoside	Sugar	Solberg: US20080196908

Table B.2 Identified detergents (identified by CAS) incl. CAS/EC identifier, the substance name, chemical group and the supplier and/or product name

CAS	EC	Substance name	Chemical group	Supplier and Product Name
308062-28-4	608-528-9 / 931-292-6	Amines, C12-14 (even numbered) - alkyldimethyl, N-oxides	Alkylamine	Dafo Fomtec AB: Enviro 3% ICAO, Enviro USP Dr Sthamer: vaPUREx LV 1% F-10 #7141
68155-09-9	268-938-5	Amides, coco, N-(3-(dimethylamino)propyl), N-oxides	Alkylamine	Angus Fire: Syndura (6% fluorine-free foam)
70592-80-2	274-687-2	Amines, C10-16-alkyldimethyl, N-oxides	Alkylamine	Angus Fire: Syndura (6% fluorine-free foam)
269-087-2	68187-32-6	l-Glutamic acid, N-coco acyl derivs., monosodium salts	Alkylamine	
1469983-49-0	939-455-3	1-Propanaminium, N-(3-aminopropyl)-2-hydroxy-N,N-dimethyl-3-sulfo-, N-(C8-18(even numbered) acyl) derivs., hydroxides, inner salts	Alkylbetaine	Dafo Fomtec AB: Enviro 3x3 Plus, Enviro 3x3 Ultra, Enviro 3x6 Plus, Environ 6x6 Plus, LS aMax, Silvara APC 1
147170-44-3	604-575-4 / 931-333-8	1-Propanaminium, 3-amino-N-(carboxymethyl)-N,N-dimethyl-, N-(C8-18(even numbered) and C18 unsaturated acyl) derivs., hydroxides, inner salts	Alkylbetaine	Dr Sthamer: MOUSSOL®–FF 3/6 F-15 #7941
61789-40-0	931-296-8	1-Propanaminium, 3-amino-N-(carboxymethyl)-N,N-dimethyl-, N-(C12-18(even numbered) acyl) derivs., hydroxides, inner salts	Alkylbetaine	OneSeven of Germany GmbH: OneSeven Foam Concentrate Class A Solberg: Solberg Patent US20080196908
64265-45-8	264-761-2	N-(2-hydroxyethyl)-N-[2-[(1-oxooctyl)amino]ethyl]-β-alanine	Alkylbetaine	vs FOCUM: Silvara APC 1, Silvara APC 3x3, Silvara APC 3x6, Silvara ZFK (0.5%)
68139-30-0	268-761-3	Cocamidopropyl hydroxysultaine	Alkylbetaine	Solberg: US20080196908

CAS	EC	Substance name	Chemical group	Supplier and Product Name
13150-00-0	236-091-0	Sodium 2-[2-[2-(dodecyloxy)ethoxy]ethoxy]ethyl sulphate	Alkylsulfate	Kempartner AB : Unifoam Bio Yellow
139-96-8	205-388-7	2-[bis(2-hydroxyethyl)amino]ethanol; dodecyl hydrogen sulfate	Alkylsulfate	Dr Sthamer: Sthamex SVM Dr Sthamer: Moussol-FF® 3/6 Kempartner AB: Unifoam S Kempartner AB: Unifoam OneSeven of Germany GmbH: OneSeven ® Foam Concentrate Class B-AFFF vs FOCUM: Silvara 1 (1%) vs FOCUM: Silvara APC 1 vs FOCUM: Silvara APC 3x3 vs FOCUM: Silvara ZFK (0.5%)
142-31-4	205-535-5	Sodium octyl sulphate	Alkylsulfate	Angus Fire (Angus International: Angus Fire, National Foam and Eau et Feu.) : Syndura (6% fluorine-free foam) Chemguard: 3% AFFF Foam Concentrate (C303) Chemguard: 3% Low Temp AFFF (C3LT) Dafo Brand AB: AFFF 3-6 % Fire Services Plus: FireAde Fire Services Plus: FireAde AR AFFF OneSeven of Germany GmbH: OneSeven ® Foam Concentrate Class B-AFFF OneSeven of Germany GmbH: OneSeven ® Foam Concentrate Class B-AFFF-AR Solberg : Solberg Patent US20080196908 Dr Sthamer: TRAINING FOAM-N 1% F-0 #9141 vs FOCUM: Silvara ZFK (0.5%)
142-87-0	205-568-5	Sodium decyl sulfate	Alkylsulfate	Chemguard: 3% AFFF Foam Concentrate (C303) Chemguard: 3% Low Temp AFFF (C3LT) Chemguard: 6% AFFF Foam Concentrate (C603) Chemguard: 6% Low Temp AFFF (C6LT) Dafo Brand AB: AFFF 3-6 % Dafo Fomtec AB: LS xMax Dafo Fomtec AB: MB -20 Solberg : Solberg Patent US20080196908 Dr Sthamer: TRAINING FOAM-N 1% F-0 #9141 vs FOCUM: Silvara 1 (1%) Solberg : Solberg Patent US20080196908
143-00-0	205-577-4	Dodecyl hydrogen sulfate;2-(2-hydroxyethylamino)ethanol	Alkylsulfate	Solberg: US20080196908
151-21-3	205-788-1	Sodium dodecyl sulphate	Alkylsulfate	Fire Services Plus: FireAde; FireAde AR AFFF
2235-54-3	218-793-9	Ammonium alkyl ether sulphate	Alkylsulfate	Kempartner AB: Unifoam, Unifoam S
25882-44-4	247-310-4	disodium;4-[2-(dodecanoylamino)ethoxy]-4-oxo-3-sulfonatobutanoate	Alkylsulfate	Angus Fire (Angus International: Angus Fire, National Foam and Eau et Feu.) : Expandol (aka Expandol 1-3), Expandol LT (aka Expanol 1-3LT)

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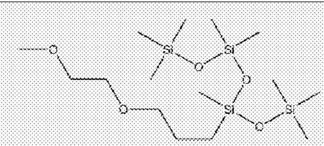
CAS	EC	Substance name	Chemical group	Supplier and Product Name
273-257-1	68955-19-1	Sulfuric acid, mono-C12-18-alkyl esters, sodium salts	Alkylsulfate	Identified by ECHA
287-809-4	85586-07-8	Sulfuric acid, mono-C12-14-alkyl esters, sodium salts	Alkylsulfate	Identified by ECHA
3088-31-1	221-416-0	Sodium 2-(2-dodecyloxyethoxy)ethyl sulphate	Alkylsulfate	Buckeye Fire Equipment Company: Buckeye High Expansion Foam (BFC-HX) (aka Hi-Ex 2.2)
577-11-7	209-406-4	1,4-bis(2-ethylhexoxy)-1,4-dioxobutane	Alkylsulfate	Dr Sthamer: STHAMEX® K 1% F-15 #9143
68081-96-9	268-364-5	Sulfuric acid, mono-C10-16-alkyl esters, ammonium salts	Alkylsulfate	Orchidee Fire: Orchidex BlueFoam 3x3 Verde Environmental Inc (Micro Blaze): Micro-Blaze Out
68439-57-6	931-534-0, 270-407-8	Sulfonic acids, C14-16-alkane hydroxy and C14-16-alkene, sodium salts	Alkylsulfate	Dafo Fomtec AB: Enviro 3x3 Plus, Enviro 3x6 Plus, Environ 6x6 Plus Dr Sthamer: STHAMEX® 3% F6 Multi-purpose detergent foam, STHAMEX® K 1% F-15 #9143 vaPUREx LV 1% F-10 #7141
68877-55-4	272-563-2	Sodium 3-[2-(2-heptyl-4,5-dihydro-1H-imidazol-1-yl)ethoxy] propionate	Alkylsulfate	OneSeven of Germany GmbH: OneSeven ® Foam Concentrate Class B-AFFF, OneSeven ® Foam Concentrate Class B-AFFF-AR
68877-55-4	272-563-2	Sodium 3-[2-(2-heptyl-4,5-dihydro-1H-imidazol-1-yl)ethoxy] propionate	Alkylsulfate	OneSeven of Germany GmbH: OneSeven ® Foam Concentrate Class B-AFFF, OneSeven ® Foam Concentrate Class B-AFFF-AR
68891-38-3	500-234-8	Sodium laureth sulfate	Alkylsulfate	Angus Fire: Expandol (aka Expandol 1-3), Expandol LT (aka Expanol 1-3LT), Respondol ATF 3-6% Dafo Fomtec AB: Enviro 3% ICAO, Enviro USP, LS xMax, Trainer E-lite
85338-42-7	286-718-7, 939-332-4	Sulfuric acid, mono-C8-10 (even numbered)-alkyl esters, sodium salts	Alkylsulfate	Angus Fire: Respondol ATF 3-6% Dafo Fomtec AB: Enviro 3x3 Ultra, LS aMax
85665-45-8	939-262-4	Sulfuric acid, mono-C8-14 (even numbered)-alkyl esters, compds. with triethanolamine	Alkylsulfate	Dr Sthamer: MOUSSOL®–FF 3/6 F-15 #7941, MOUSSOL®–FF 3/6 F-5 #7942, STHAMEX® 2% F6 Multi-purpose detergent foam, STHAMEX-SV/HT 1% F-5 #9142, TRAINING FOAM-N 1% F-0 #9141
90583-18-9	939-265-0, 292-216-9	Sulfuric acid, C12-14 (even numbered)-alkyl-esters, compds. with triethanolamine	Alkylsulfate	Dafo Fomtec AB: Enviro 3% ICAO, Enviro USP OneSeven of Germany GmbH: OneSeven Foam Concentrate Class A vs FOCUM: Silvara APC 3x6 Unifoam Bio Yellow
90583-25-8	292-224-2	Sulfuric acid, mono-C6-12-alkyl esters, sodium salts	Alkylsulfate	
na	919-131-8	Fatty alcohol polyglycol ether sulfate, sodium salt	Alkylsulfate	BASF: Emulphor® FAS 30

CAS	EC	Substance name	Chemical group	Supplier and Product Name
na	944-611-9	Reaction mass of C-isodecyl and C-isoundecyl sulphonatosuccinate	Alkylsulfate	Respondol ATF 3-6%
4292-10-8	224-292-6	(carboxymethyl)dimethyl-3-[(1-oxododecyl)amino]propylammonium hydroxide	Detergent	vs FOCUM: Silvara 1 (1%), Silvara ZFK (0.5%)

Table B.3 Siloxanes (identified by CAS) incl. CAS/EC identifier, the substance name, chemical group and the supplier and/or product name

CAS	EC	Substance name	Chemical group	Supplier & Product Name	Chemical structure
117272-76-1	601-468-4	Siloxanes and Silicones, 3-hydroxypropyl Me, ethers with polyethylene glycol mono-Me ether	Siloxanes	1% AFFF Denko 3% AFFF Denko 6% AFFF Denko Alcohol AFFF 3% - 6% Single or Double Strength Denko	

In addition, publications by Hetzer et al. presented various sugar-based siloxanes for which CAS-numbers are not available. For more information on these substances please refer to the individual publications[14].

Proteins

Regarding protein-based foams only one substance with a CAS number could be identified. This belongs to silk-based protein hydrolysate (CAS 306-235-8). However, the associated product/foam manufacturer was not identified. Some SDS mention proteins from horn and hoof (National Foam) or hydrolysed protein (Gepro Group PROFOAM 806G). In these cases, no CAS number was given.

PFAS

Based on the CAS-identified PFAS-substances that were/are used in AFFF the following grouping is used, indicated in brackets is the number of CAS-identified substances:

- Unsubstituted long chain PFAS (14)
- Unsubstituted short chain PFAS (8)
- Substituted short and long chain PFAS (12)
- Fluorotelomers (22)
- Others (7)

[14] Hetzer, R., Kümmerlen, F., Blunk, D. Auf dem Weg vom Siloxantensid zum fluorfreien AFFF.
Hetzer, R., Kümmerlen, F., Wirz, K., Blunk, D. (2014): Fire testing a new fluorine-free AFFF based on a novel class of environmentally sound high-performance siloxane surfactants. Fire Safety Science, 11, 1261-1270.
Hetzer, R. H., Kümmerlen, F. (2016): The Extinguishing Performance of Experimental Siloxane-Based AFFF.
Hetzer, R. H., Kümmerlen, F., Blunk, D. (2015). Fire Testing of Experimental Siloxane-Based AFFF: Results from New Experiments. Paper presented at the Conference Paper, Suppression, Detection and Signaling Research and Applications Symposium (SUPDET 2015), Orlando (Florida, USA).

Long Chain PFAS

Table B.4 PFSAs (identified by CAS) with ≥C6 incl. CAS/EC identifier, the designation, the acronym and the supplier and/or product name

CAS	EC	Designation (synonyms)	Acronym	Supplier and Product Name
355-46-4	206-587-1	Perfluorohexane sulfonic acid	PFHxS	Ansul AFFF Ansulite® 3M LightWater Angus Fire, na Angus Fire, 2000 ; Niagara 1-3, Angus Fire, 1997; Forexpan Angus Fire, 2007; Hi Combat A ™ 3M, 2005; ATC-603 Light water ATC3 3M, 1999; FC-203FC Light water Brand AFFF 3M 1999 3M 1992 3M 1993 3M 1998 (slightly different shares) 3M 1989 3M 1988
375-92-8	206-800-8	perfluoroheptane sulfonic acid	PFHpS	3M 1992 3M 1993 3M 1998 (slightly different shares) 3M 1989 3M 1988
1763-23-1	217-179-8	Perfluorooctanesulfonic acid	PFOS	3M AFFF ("PFSAs have been components of 3M AFFF from the 1970s to 2001") 3M LightWater FC-203FC 3M, 2005; ATC-603 Light water ATC3 3M, 1999; FC-203FC Light water Brand AFFF 3M 1992 3M 1993 3M 1998 (slightly different shares) 3M 1988 3M 1989 Ansul Ansulite® AFFF Angus Fire, na Angus Fire, 2000 ; Niagara 1-3, Angus Fire, 1997; Forexpan Angus Fire, 2007; Hi Combat A ™ Hazard Control Technologies, Inc., 2003 F-500 Dr. Sthamer STHMEX-AFFF 3%
68259-12-1	na	Perfluoronone sulfonic acid	PFNS	3 M Lightwater PFSAs have been components of 3M AFFF from the 1970s to 2001
335-77-3	206-401-9	Perfluorodecanesulfonic acid	PFDS	3M Ansul AFFF Angus Fire, na Fomtec MB 5
749786-16-1	na	Perfluoroundecan sulfonic acid	PFUnDS	No product/supplier is mentioned; Publications are based on environmental samples

Table B.5 PFCAs (identified by CAS) with ≥C7 incl. CAS/EC identifier, the designation, the acronym and the supplier and/or product name

CAS	EC	Designation (synonyms)	Acronym	Supplier and Product Name
375-85-9	206-798-9	Perfluoroheptanoic acid	PFHpA	Ansul AFFF Ansulite® 3M LightWater Angus Fire, na Angus Fire, 2000 ; Niagara 1-3, Angus Fire, 1997; Forexpan Angus Fire, 2007; Hi Combat A ™ Angus Fire, 2004 Tridol S 3 % 3M, 2005; ATC-603 Light water ATC3 3M, 1999; FC-203FC Light water Brand AFFF FC-203FC Light Water 3M OneSeven B-AR ARC Miljö Towalex 3x3 Towalex 3% master Sthamex AFFF-P 3%
335-67-1	206-397-9	Perfluorooctanoic acid	PFOA	Ansul AFFF Ansulite® 3M LightWater Angus Fire, na Angus Fire, 2000 ; Niagara 1-3, Angus Fire, 1997; Forexpan 3M, 2005; ATC-603 Light water ATC3 3M, 1999; FC-203FC Light water Brand AFFF 3M 1999 3M 1992 3M 1993 3M 1998 (slightly different shares) 3M 1989 3M 1988 OneSeven B-AR ARC Miljö Towalex plus Towalex 3x3 Towalex 3% super Towalex 3% master Sthamex AFFF-P 3% FC-203FC Light Water 3M
375-95-1	206-801-3	Perfluorononanoic acid	PFNA	Ansul AFFF Ansulite® 3M LightWater Angus Fire, na Angus Fire, 2000 ; Niagara 1-3, Angus Fire, 1997; Forexpan OneSeven B-AR ARC Miljö Towalex 3x3 Towalex 3% master Hazard Control Technologies, Inc., 2003 F-500
335-76-2	206-400-3	Perfluorodecanoic acid	PFDA	Ansul AFFF Ansulite® 3M LightWater 3M FC-203FC Light Water Fomtex Arc 3x3 Towalex plus Towalex 3x3 Towalex 3% master

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CAS	EC	Designation (synonyms)	Acronym	Supplier and Product Name
2058-94-8	218-165-4	Perfluoroundecanoic acid	PFUnDA	3M LightWater 3M LightWater FC-203FC Ansul Ansulite® ANSUL Ansulite 6 % AFFF (Formula 1559-22 ICAO-B)
307-55-1	206-203-2	Perfluorododecanoic acid	PFDoDA	Ansul AFFF Ansulite® 3M LightWater Sthamex F-15 Towalex 3% master
72629-94-8	276-745-2	Perfluorotridecanoic acid	PFTrDA	PFCAs were primary components in early 3M AFFFs from 1965 up to 1986
376-06-7	na	Perfluorotetradecanoic acid	PFTeDA	3M AFFFs from 1965 up to 1987 Ansul AFFF FC-203FC Light Water 3M
16517-11-6	240-582-5	Perfluorostearic acid	PFODA	No product/supplier is mentioned; Publications are based on environmental samples

Short chain PFAS

Table B.6 PFSAs (identified by CAS) with <C6 incl. CAS/EC identifier, the designation, the acronym and the supplier and/or product name

CAS	EC	Designation (synonyms)	Acronym	Supplier and Product Name
354-88-1	na	Perfluoroethane sulfonic acid	PFEtS	3M AFFFs Shorter chains C2-C3 PFSAs used in from 1988 to 2001
423-41-6	na	Perfluoropropane sulfonic acid	PFPrS	3M AFFFs Shorter chains C2-C3 PFSAs used in from 1988 to 2001
375-73-5	206-793-1	Perfluorobutanesulfonic acid	PFBS	Ansul AFFF Ansulite® 3M LightWater Angus Fire, na Angus Fire, 2000 ; Niagara 1-3, Angus Fire, 1997; Forexpan Angus Fire, 2007; Hi Combat A ™ 3M, 2005; ATC-603 Light water ATC3 3M, 1999; FC-203FC Light water Brand AFFF 3M 1999 3M 1992 3M 1993 3M 1998 (slightly different shares) 3M 1989 3M 1988
2706-91-4	220-301-2	Perfluoropentane sulfonic acid	PFPeS	No product/supplier is mentioned; Publications are based on environmental samples

wood.

Table B.7 PFCAs (identified by CAS) with <C7 incl. CAS/EC identifier, the designation, the acronym and the supplier and/or product name

CAS	EC	Designation (synonyms)	Acronym	Supplier and Product Name
375-22-4	206-786-3	perfluoro-n-butanoic acid	PFBA	Ansul AFFF Ansulite® 3M LightWater Angus Fire, na Angus Fire, 2000 ; Niagara 1-3, Angus Fire, 1997; Forexpan Angus Fire, 2007; Hi Combat A ™ 3M, 2005; ATC-603 Light water ATC3 3M, 1999; FC-203FC Light water Brand AFFF OneSeven B-AR ARC Miljö Towalex 3x3 Towalex 3% master Sthamex AFFF-P 3%
2706-90-3	220-300-7	Perfluoropentanoic acid	PFPeA	3M LightWater FC-203FC 3M 1999 3M 1992 3M 1993 3M 1998 (slightly different shares) 3M 1989 3M 1988 Angus Fire, 2000 ; Niagara 1-3, Angus Fire, 1997; Forexpan Ansul AFFF Ansulite®
307-24-4	206-196-6	Perfluorohexanoic acid	PFHxA	Ansul AFFF Ansulite® 3M LightWater Angus Fire, na Angus Fire, 2000 ; Niagara 1-3, Angus Fire, 1997; Forexpan 3M, 2005; ATC-603 Light water ATC3 3M, 1999; FC-203FC Light water Brand AFFF 3M 1999 3M 1992 3M 1993 3M 1998 (slightly different shares) 3M 1989 3M 1988 OneSeven B-AR ARC Miljö Towalex plus Towalex 3x3 Towalex 3% super Towalex 3% master Sthamex AFFF-P 3%

Derivates of perfluoroalkyl sulfonic PFAS (also PASF-based substances)

Table B.8 Identified derivates of perfluoroalkyl sulfonic PFAS (also PASF-based substances)

CAS	EC	Designation (synonyms)	Acronym	Supplier and Product Name
13417-01-1	236-513-3	Perfluoroalkyl sulfonamido amines	PFOSaAm	National Foam ; Ansulite;

CAS	EC	Designation (synonyms)	Acronym	Supplier and Product Name
				3M lightwater; 3M
167398-54-1	na	Perfluoroheptane sulfonamidoethanol	C7-FASA (PFHpSA)	3 M Lightwater was used from 1988 until 2001 OR Ansul (telomer-based foam)
647-29-0	na	na	C8-PFSiA (PFOSI)	3M 1988 3M 1989
2991-50-6 / 1336-61-4	221-061-1	N-Ethyl perfluorooctane sulfonamidoacetic acid	EtFOSAA	No product/supplier is mentioned; Publications are based on environmental samples
4151-50-2	223-980-3	N-Methyl perfluorooctane sulfonamidoacetic acid	EtFOSE	No product/supplier is mentioned; Publications are based on environmental samples
68298-12-4	na	N-Methylperfluorobutanesulfonamide	FBSA	No product/supplier is mentioned
2806-24-8	na	perfluorooctane sulfonamido acetic acid	FOSAA	No product/supplier is mentioned; Publications are based on environmental samples
754-91-6	212-046-0	Perfluorooctane sulfonamide	FOSA	No product/supplier is mentioned; Publications are based on environmental samples
10116-92-4	na	na	FOSE	No product/supplier is mentioned; Publications are based on environmental samples
2355-31-9	na	N-methyl perfluorooctanesulfonamidoacetic acid	N-MeFOSA	No product/supplier is mentioned; Publications are based on environmental samples
24448-09-7	246-262-1	N-Methyl perfluorooctane sulfonamidoethanol	N-MeFOSE	No product/supplier is mentioned; Publications are based on environmental samples
68555-77-1	271-455-2	perfluoroalkyl sulfonamido amines	PFBSaAm	No product/supplier is mentioned; Publications are based on environmental samples
80475-32-7	279-481-6	N-[3-(Dimethyloxidoamino)propyl] -3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluor-1-octanesulfonamid	na	Dupont, Forafac® 1183
133875-90-8	na	(Carboxymethyl)dimethyl [3-(gamma-omega-perfluor-1-C6-14-Alkansulfonamid)propyl)ammonium (inneres Salz)	na	Dupont, Forafac® 1203

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Fluorotelomers

Table B.9 Fluorotelomer (identified by CAS) substances incl. CAS/EC identifier, the designation, the acronym and the supplier and/or product name

CAS	EC	Designation (synonyms)	Acronym	Supplier and Product Name
34455-35-1	na	10:2 Fluorotelomer sulfonamide alkylbetaine	10:2 FTAB	F-500, Hazard Control Tech., 1997 National Foam 2005 National Foam 2007 National Foam 2008 Fire Service Plus AFFF 2011 National Foam 2003-2008
53826-13-4	na	10:2 Fluorotelomer carboxylic acid	10:2 FTCA	No product/supplier is mentioned; Publications are based on environmental samples
70887-84-2	na	10:2 fluorotelomer unsaturated carboxylic acid	10:2 FTUCA	No product/supplier is mentioned; Publications are based on environmental samples
278598-45-1	na	Fluorotelomer sulfonamido betaines	12:2 FtSaB	3M Ansul, 2006 Ansul Anulite ARC
757124-72-4	816-391-3	Fluorotelomer sulfonates	4:2 FTS	Angus Fire, 2004 Tridol S 3% Ansul 2002 Anslite 3% AFFF-DC-6 Hazard Control Tech 1197 F-500 National Foam
1432486-88-8	na	4:2 fluorotelomer thioamido sulfonates	4:2 FtTAoS	Ansul AFFF formulations Angus Fire, 2004 Tridol S Ansul, 2002 Ansulite 3% AFFF DC-3 Ansul, 2006 Ansul Anulite ARC Hazard Control Tech., 1997 F-500 Chemguard Ansul Angus
171184-02-4	na	5:1:2 fluorotelomer betaine	5:1:2 FTB	3M Ansul, 2002 Ansulite 3% AFFF DC-3 Buckeye 2009 Buckeye AFFF 2004
171184-14-8	na	5:3 fluorotelomer betaine	5:3 FTB	3M Buckeye
34455-29-3	252-046-8	6:2 Fluorotelomer sulfonamide betaine	6:2 FTAB	Chemours, STHAMEX® -AFFF 3% F-15 #4341 Dupont Forafac 1157 Dr. Sthamer, 3M National Foam F-500, Hazard Control Tech., 1997 (Foam 1) Angus Fire, 2004 Tridol S Angus Fire, 2000 Niagara 1-3 Chemours
647-42-7	211-477-1	6:2 Fluorotelomer alcohol	6:2 FTOH	No product/supplier is mentioned; Publications are based on environmental samples
27619-97-2	248-580-6	6:2 Fluorotelomer Sulfonate	6:2 FTS	Dr. Richard Sthamer GmbH & Co. KG STHMEX-AFFF 3% Hazard Control Tech., 1997 F-500 Angus Fire, 2004 Tridol S 3 %

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CAS	EC	Designation (synonyms)	Acronym	Supplier and Product Name
				Angus Fire, 2000 ; Niagara 1-3, Angus Fire, 1997; Forexpan Angus Fire, 2004 Tridol S 3 % Ansul, 2002 Ansulite 3 % AFFF - DC-4 Ansul, 2006; Ansul Anulite ARC National Foam 2005 National Foam 2007 National Foam 2008 (slightly different shares)
1383438-86-5	na	6:2 fluorotelomer sulfonamide amine	6:2 FtSaAm	3M, National Foam 2005 National Foam 2007 National Foam 2008 (slightly different shares)
88992-47-6	na	6:2 fluorotelomer thioether amido sulfonic acid	6:2 FtTAoS	Angus Fire, 2004 Tridol S Ansul 1986 Ansul 1987 Angus Fire, 2000 Niagara 1-3 Ansul, 2002 Ansulite 3% AFFF DC-3 Ansul 2009 Ansul 2010 Chemguard 2008 F-500, Hazard Control Tech., 1997
88992-46-5	na	6:2 fluorotelomer thio hydroxy ammonium	6:2 FtTHN+	3M
171184-03-5	na	7:1:2 fluorotelomer betaine	7:1:2 FTB	3M Buckeye 2009
171184-15-9	na	7:3 fluorotelomer betaine	7:3 FTB	Buckeye Ansul, 2002 Ansulite 3% AFFF DC-3
27854-31-5	na	8:2 Fluorotelomer carboxylic acid	8:2 FTCA	F-500, Hazard Control Tech., 1997
34455-21-5	na	8:2 Fuorotelomer sulfonamide betaine	8:2 FTAB	National Foam, F-500, Hazard Control Tech., 1997 National Foam 2005 National Foam 2007 National Foam 2008 (slightly different shares) Fireade
39108-34-4	254-295-8	Fluorotelomer sulfonates	8:2 FTS	Ansul, 2002 Anslite 3 % AFFF - DC-5 Hazard Control Tech., 1997 F-500 Angus Fire, 2000 ; Niagara 1-3, Angus Fire, 1997; Forexpan National Foam 2005 National Foam 2007 National Foam 2008
1383439-45-9	na	8:2 fluorotelomer thioamido sulfonates	8:2 FtTAoS	Chemguard, Ansul, 2006; Ansul Anulite ARC; Ansul, 2002 Ansulite 3% AFFF DC-3 Angus Fire, 2004 Tridol S Angus Fire, 2000; Niagara 1-3 Hazard Control Tech., 1997 F-500;

CAS	EC	Designation (synonyms)	Acronym	Supplier and Product Name
171184-04-6	na	9:1:2 fluorotelomer betaine	9:1:2 FTB	3M Buckeye AFFF 2004 Buckeye 2009
171184-16-0	na	9:3 fluorotelomer betaine	9:3 FTB	Buckeye 2009 3M 1988 3M 1989 3M 1993A 3M 1993B 3M 1998 3M 2001 Ansul, 2002 Ansulite 3% AFFF DC-3

Other PFAS substances

Table B.10 Other per- or polyfluorinated substances (identified by CAS) incl. CAS/EC identifier, the designation, the acronym and the supplier and/or product name

CAS	EC	Designation (synonyms)	Acronym	Supplier and Product Name
1280222-90-3	480-310-4	ammonium 2,2,3 trifluor-3-(1,1,2,2,3,3-hexafluoro-3-trifluormethoxypropoxy), propionate	ADONA	Mentioned in annex_xv_svhc_ec_206-397-9_pfoa_11549 as a substitute. However no other source supports this information.
756-13-8	616-243-6 / 436-710-5	Dodecafluoro-2-methylpentan-3-one	na	3M NOVEC TM 1230
161278-39-3	500-631-6	Poly(1,1,2,2-tetrafluoro-1,2-ethanediyl), α-fluoro-ω-2-[3-((carboxylatomethyl) dimethylammonio)propylaminosulfonyl]ethyl-	na	PROFOAM Profilm AFFF
70969-47-0	na	Thiols, C8-20, gamma-omega-perfluoro, telomers with acrylamide	Thiols, C8-20, gamma-omega-perfluoro, telomers with acrylamide	Towalex 3% master
70829-87-7	na	Sodium p-perfluorous nonenoxybenzene sulfonate	OBS	No product/supplier is mentioned; Publications are based on environmental samples